Testimony for the Committee on Science
of the
U.S. House of Representatives

Field Briefing on:
Innovation and Information Technology: The Government, University, and Industry Roles in Information Technology Research and Commercialization

given by

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Honorable Members of the Committee on Science of the House of Representatives of the United States, I would like to thank you for inviting me to speak on the important subject of how the government-industry-university research partnership maintains US competitiveness in the global information technology (IT) market. As a representative of industry – the semiconductor industry segment of information technology – I will be responding from the perspective of the "hardware" side of the IT industry, specifically the semiconductor chips that are the heart of all information systems. Even more specifically, my comments are most directly derived from the issues of the technology intensive domains of logic processors and high-density memory chips.

Background

It is worth reminding ourselves what the semiconductor segment achieves and the cost of that achievement, usually referred to as "Moore's Law":

- This year, ~1 quintillion transistors and/or memory bits will be manufactured on ~100 billion chips. They will all work.
- A single 300 mm wafer today contains as much memory as the entire world's production of DRAM in 1985. One gigabit of DRAM cost $32,000 in 1985, but is a mere $8 today.
- Semiconductors became the world's first large-scale nanotechnology industry several years ago when the 90 nanometer chip generation went into volume production. Today, transistors with active areas less than 50 nanometers across with insulating materials applied to them in layers only a few nanometers thick are being produced. In less than a decade, these dimensions will be halved again.
- 15-20% of semiconductor revenues are spent on R&D. A single 300 mm wafer fabrication plant costs ~$3-4 billion. Most are being built outside the US.
- Ultimately, the semiconductor industry is an innovation power house and among the world's highest in value-add and economic multiplier.

Much of the world's information technology industry growth and concomitant wealth and opportunity creation depends upon the continued trust and belief that an impossible product, designed today, will come to market just in time for smaller, faster, denser chips to enable it.

SEMATECH is an R&D consortium with members including most of the world's largest leading edge semiconductor manufacturers. The consortium was spawned in a previous era (1987) when the question of US competitiveness in the IT marketplace was one of active concern. Initiated as a 50-50 partnership of US government and US industry, SEMATECH was instrumental in turning the tide for semiconductor manufacturing and the chip manufacturing equipment supply chain in America – a clear legacy of a government-industry partnership that worked. The world of today is a very different place (although the questions we find ourselves asking seem familiar). After its early success, SEMATECH flexibly adapted to the global environment of our industry, and is today an international, structured family of R&D organizations, which continues to propel the industry forward.

Committee Questions
The Committee has laid out three key questions to be addressed in this hearing, and I will answer them in light of the last 20 years of semiconductor industry research, development, and commercialization collaboration as embodied in SEMATECH.

1. **How does the federal investment in information technology research promote innovation in information technology and foster the development and commercialization of new applications?**

The innovation ecosystem in any area, including IT, has many layers. The most fundamental is the basic science and engineering research that expands the boundaries of knowledge and brings new ideas, useful or not, into the environment. At higher levels in the ecosystem, we find product development, commercialization, manufacturing, and industrial scaling. Federal investment in information technology research has and will play a crucial role in quite literally enabling the basic research layer of the IT ecosystem. Industries broadly have to a large degree come to rely on universities for this research, and to an increasing degree, anticipate its funding through federal grants and sponsored research. Beginning in the 1980's and enabled by the National Cooperative Research and Production Act, the semiconductor industry began the task of constructing a cooperative framework for solving the increasingly daunting problem of bringing together all the technologies needed for the industry. It was realized that much of that effort is "pre-competitive," that is, needed by all participants but not strongly connected to their own core business value propositions.

Figure 1 illustrates the collaboration pipeline of the semiconductor industry today. Although the specific companies at each stage vary somewhat, there is consistent participation by advanced logic and memory manufacturers all through this pipeline. The

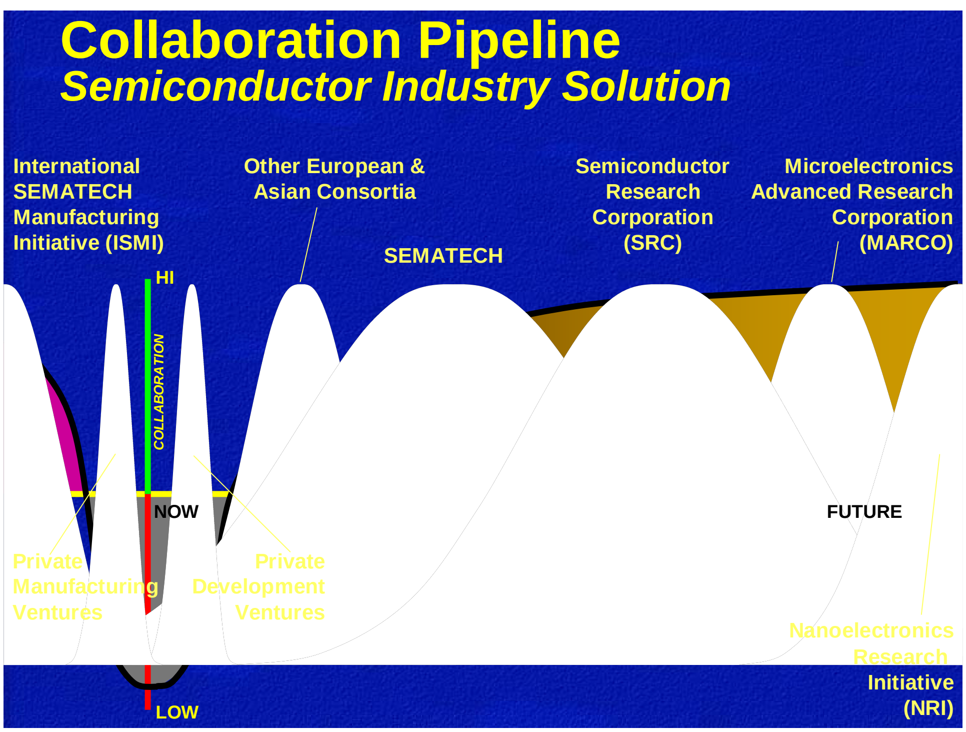

Figure 1. Collaboration pipeline of the semiconductor industry.

pre-competitive R&D efforts in the semiconductor industry globally are coordinated through the *International Technology Roadmap for Semiconductors* (ITRS), a (now web-based) document of nearly 1,000 pages, annually updated by nearly 1,000 contributors around the world. Note that this pipeline is not exclusively embodied in the US. While it is true today that the US enjoys a legacy position of semiconductor leadership (as well as a continued vested interest in that leadership driven at the federal level for defense and homeland security reasons), it is by no means an entitlement, and as the era of nanoelectronics and advanced technology convergence emerges *simultaneously* around the world, we will find ourselves competing in a pre-globalized mega-industrial complex.

In Figure 1, federal funding is heaviest in areas that are focused on the far future (right hand side) and decreasing applied as efforts converge on the competitive "now" (the vertical axis on the left). The Semiconductor Industry Association (SIA) as the representative organization of the industry in America, has established priorities for federal technology research funding (http://www.sia-online.org/backgrounders_technology_funding.cfm). I will not detail them here, but they include substantial increases in funding for the physical sciences through the NSF (through partnerships with SRC and in conjunction with the National Nanotechnology Initiative), the funding of the Focus Center Research Program (MARCO) by DOD, and specific support of NIST. This funding provides feedstock for the collaboration pipeline, although it is not sufficient to the task and additional funding from any government will assure a higher level of participative innovation for that region.

2. **What role does university research play in innovation in information technology? How do universities balance federal and industry support for research projects? What are the barriers to the use of university results in commercialization of new information technology products?**

As noted above, university research brings new ideas into the innovation ecosystem. Within the complex academic environment, there are several priorities that offer friction to the movement of these ideas to the marketplace. The most important is that a large fraction of these ideas are not honestly intended to ever go there. They are byproducts of the most significant mission of research universities – educating the scientists and engineers of the future. Commercialization (and commercializability) of these ideas is ad hoc. Even when research is directed by the funding source and the research results are specifically intended to contribute to a higher and specific mission, successful commercialization is still not assured.

One key factor in this lack of transfer is that semiconductor research often departs from the mainline of the ITRS (through its very innovative nature) and therefore sees a large barrier to entry into manufacturing. The industry's technology conveyor belt is moving at "warp speed." A professor trying to support a graduate student who needs 3-4 years to complete his PhD thesis will often select a topical point on the ITRS which his laboratory can support (processing and test equipment, etc.). Since the duration of this PhD effort can be two technology generations for the industry, it is often discovered that by the time the student has completed his work, valuable data for the industry has been obtained, but the insertion point for that research has passed – the industry picked from whatever was available and moved on. These decisions are often irreversible.

Another challenge to the commercialization of university research is found in the shear complexity and difficulty of beyond-leading-edge chip design and fabrication. A leading-edge company might employ hundreds of engineers and spend hundreds of millions of dollars developing a new chip technology. This is far beyond the capability of a university researcher, so he must focus on an increasingly small portion of the technical space and at an increasingly distant portion of the ITRS timeline. But he will almost always have significantly less capable infrastructure (usually older, donated equipment). Even in the best of circumstances, targeting these pin-point selections so that they produce, within the vagaries of research, commercially blendable results is very challenging.

A final confounding factor for technology transfer in the semiconductor industry is IP. In the semiconductor industry, large portfolios of IP are often exchanged among industry players to acquire and/or maintain leading-edge design and production and capabilities. Isolated or disconnected patents on university developments can delay, complicate, or even kill the opportunity to integrate a university result into a semiconductor manufacturing process, tool, or material effort. Unless a portfolio is constructed and actively maintained, which is a sophisticated endeavor not often possible within the administrative structure of a university research commercialization office, semiconductor research results are difficult to process through the conventional thinking of the Bayh-Dole act, despite their potential for contributing to the industry's moving forward.

3. **What areas of information technology research and what type of programs should the federal government support to maintain U.S. competitiveness? How do these areas complement the focus and investments of industry research programs?**

In addition to the specific directions provided by the SIA on research funding, R&D and manufacturing investment tax policy, and education and workforce development, I would like to offer the following for the Committee's consideration:

- **Innovation Process Connection:** As the semiconductor industry begins to mature in the coming 10-20 years, staying on Moore's Law will require a broader base of technology R&D investments than might be afforded by our industry alone. Other industries that need nanoscale fabrication, measurement techniques, and exotic materials can help support that effort if two things occur: (1) there is intentionality in technology convergence so that common industrial needs are identifying and optimized; and (2) there is sufficient and appropriate R&D infrastructure and funding direction to drive these efforts together, beginning at the research phase. Therefore, the US government could consider:
    - Offering specific support and direction to emerging technology areas requiring nanofabrication and nanomanufacturing to construct roadmaps with clear linkages to the ITRS.
    - Using the collaboration example of the semiconductor industry as a model and offer support to other IT (and emerging technology!) segments in building a collaboration pipeline that incorporates the best US capabilities.
- **Innovation Infrastructure Connection:** The federal government can form partnerships with states to create higher funding impact by matching state economic development programs targeted at semiconductor manufacturing and technology development. This should be particularly supported when existing leading-edge semiconductor infrastructure (buildings, labs, equipment, know-how) can be expanded for multiple use by emerging technology researchers. Inter-agency collaborations with the states in convergent technology infrastructure should be increased and rewarded.

- **Innovation People Connection:** The federal government can identify additional funding for nanoelectronics and other convergent technology education and workforce development programs that engage advanced sites for hands-on training purposes. Again, partnerships with the states will bring the largest impact. A significant challenge requiring collaboration of educators *and industry* is early experiential exposure of high school students to technology career opportunities to motivate them to engage the curriculum of the 21st century.

In the modern world, no country can afford to lose any of its technology research, development, and manufacturing base, even as these are increasingly interconnected due to complexity and high cost. I have fully avoided specific technical program recommendations today, as they are well documented elsewhere, and these additional details can be provided as needed. As an independent industry representative organization, with a long, rich history of driving technology development, transferring research results from universities, commercializing technology, roadmapping the collaboration pipeline, and assembling and operating sophisticated R&D infrastructure, we offer to you to please contact us for further discussions on any of these matters.